

1 In the claims:

2 1. An image enhancement method, comprising:

3 capturing an image;

4 constructing a multi-resolution structure comprising one or more resolution layers;

5 processing each resolution layer using an iterative algorithm having at least one

6 iteration;

7 projecting each processed resolution layer to a subsequent resolution layer;

8 up-calling each projected resolution layer to the subsequent resolution layer; and

9 using the projected resolution layers to estimate an illumination image.

10 2. The method of claim 1, further comprising, for each of one or more iterations:

11 calculating a gradient of a penalty functional; and

12 computing an optimal line-search step size.

13 3. The method of claim 2, wherein the penalty functional is given by:

14 
$$F[l] = \int_{\Omega} (|\nabla l|^2 + \alpha(l-s)^2 + \beta|\nabla(l-s)|^2) dx dy;$$

15 subject to  $l \geq s$  and  $\langle \nabla l, \vec{n} \rangle = 0$  on  $\partial\Omega$ ; wherein  $\Omega$  is a support of the image,  $\partial\Omega$  is an image

16 boundary,  $\vec{n}$  is a normal to the image boundary, and  $\alpha$  and  $\beta$  are free non-negative real

17 numbers

18 4. The method of claim 2, wherein the penalty functional is given by:

19 
$$F[l] = \int_{\Omega} (w_1(\nabla s)|\nabla l|^2 + \alpha(l-s) + \beta w_2(\nabla s)|\nabla l - \nabla s|^2) dx dy$$

20 where  $w_1$  and  $w_2$  are non-linear functions of the gradient.

21 5. The method of claim 1, wherein the iterative algorithm is a Projected Normalized

22 Steepest Descent algorithm.

23 6. The method of claim 1, wherein the iterative algorithm is a Steepest Descent

24 algorithm.

25 7. The method of claim 1, wherein a set of constraints comprise that the illumination is  
26 greater than the image intensity,  $L > S$ .

27 8. The method of claim 1, further comprising applying penalty terms, the penalty terms,  
28 comprising:

29 that the illumination is spatially smooth;

30 that the reflectance is maximized;

31 that the reflectance is piece-wise smooth.

9. The method of claim 1, further comprising:

computing the reflectance image based on the captured image and the estimated illumination image;

computing a gamma correction factor;

applying the gamma correction factor to the estimated illumination image; and

multiplying the gamma-corrected illumination image and the reflectance image,

thereby

producing a corrected image.

10. A system, embodied in a computer-readable medium, for enhancing digital images, comprising:

a log module that receives an input digital image  $S$  and computes a logarithm  $s$  of the input digital image;

an illumination estimator module that produces an estimate  $l^*$  of an illumination component  $L$  of the input digital image  $S$ , wherein the estimator module employs a construct comprising one or more resolution layers, and an iterative algorithm that processes each of the one or more resolution layers; and

a summing node that sums the logarithm  $s$  and a negative of the estimate  $l^*$  to produce an estimate  $r^*$  of a logarithm of a reflectance component  $R$  of the input digital image  $S$ , wherein a processed resolution layer is used to up-scale a subsequent resolution layer.

11. The system of claim 10, wherein the iterative algorithm, for each of one or more iterations:

calculates a gradient of a penalty functional; and

computes an optimal line-search step size.

12. The method of claim 11, wherein the penalty functional is given by:

$$F[l] = \int_{\Omega} (|\nabla l|^2 + \alpha(l-s)^2 + \beta|\nabla(l-s)|^2) dx dy$$

subject to  $l \geq s$  and  $\langle \nabla l, \vec{n} \rangle = 0$  on  $\partial\Omega$ ; wherein  $\Omega$  is a support of the image,  $\partial\Omega$  is an image

boundary,  $\vec{n}$  is a normal to the image boundary, and  $\alpha$  and  $\beta$  are free non-negative real numbers.

13. The system of claim 10, wherein the penalty functional is given by:

$$F[l] = \int_{\Omega} (w_1(\nabla s)|\nabla l|^2 + \alpha(l-s) + \beta w_2(\nabla s)|\nabla l - \nabla s|^2) dx dy$$

where  $w_1$  and  $w_2$  are non-linear functions of the gradient.

- 1 14. The system of claim 10, wherein the iterative algorithm is a Projected Normalized  
2 Steepest Descent algorithm.
- 3 15. The system of claim 10, wherein the iterative algorithm is a Steepest Descent  
4 algorithm.
- 5 16. The system of claim 10, wherein each of the one or more resolution layers is projected  
6 onto constraints, and wherein the constraints comprise that the illumination is greater than the  
7 image intensity,  $L > S$ ;
- 8 17. The system of claim 10, further comprising penalty terms, the penalty terms  
9 comprising:  
10 that the illumination is spatially smooth  
11 that the reflectance is maximized; and  
12 that the reflectance is piece-wise smooth.
- 13 18. The system of claim 10, further comprising:  
14 a module that computes reflectance and illumination images based on the input  
15 digital image and the estimated illumination image;  
16 a gamma correction module that computes a gamma correction factor and applies the  
17 gamma correction factor to the estimated illumination image; and  
18 a node that multiplies the gamma-corrected illumination image and the reflectance  
19 image, thereby producing a corrected digital image.
- 20 19. A method for enhancing an image  $S$ , the image  $S$  comprising a reflectance  $R$  and an  
21 illumination  $L$ , the method comprising:  
22 constructing a multi-resolution image structure having one or more resolution layers;  
23 processing the resolution layers using an iterative algorithm;  
24 projecting the processed resolution layers onto a set of constraints, the set of  
25 constraints  
26 comprising boundary conditions and that  $L > S$ ; and  
27 using the projected resolution layers to estimate an illumination image.
- 28 20. The method of claim 19, wherein the image  $S$  is a RGB domain color image, the  
29 method further comprising:  
30 mapping colors R, G, B of the image  $S$  into a luminance/chrominance color space;  
31 applying a correction factor to a luminance layer; and  
32 mapping the luminance/chrominance colors back to the RGB domain.